Strategic Plan for the Joint Center for Satellite Data Assimilation

FY 2009-2013

Table of Contents

A Message from the JCSDA Director

Weather continues to have a profound impact on our society; human lives, and property—what's more, the activity and profitability of a wide range of economic sectors depend on it. According to estimates published by the U.S. Department of Commerce, around 20 percent—$2.75 trillion—of the overall U.S. economy is considered "weather-sensitive."

Being sensitive to weather is one thing, being sensitive to weather forecasts is something else. What are the real stakes? Let's assume that half of the weather-sensitive activities are also what one might call forecast-sensitive—they represent areas where a decision based on weather forecast input will have an economic impact. This means that a $1.4 trillion slice of the national economy is depending on weather forecasting for guidance. Let's further speculate that the maximum benefit that could potentially be realized from forecasting amounts to a relatively modest 5 percent of this $1.4 trillion total. In other words, the difference between having no advance information whatsoever and having the best possible forecasts amounts to slightly more than one half of 1 percent of the overall economy, or just over $70 billion annually.

The extreme theoretical limit of predictability of the weather is about two weeks. Now, let's try to assess "value by range" by way of a very simple mathematical model, saying that the economic benefit is proportional to the useful range of the forecast: No forecasting—zero useful range—provides no benefit, whereas useful forecast skills at the maximum range of two weeks provide the maximum benefit of $70 billion annually. This model says that the overall value to the U.S. economy of weather forecasting is an astonishing *$200 million per year for each hour of useful forecast range!*

It is, therefore, not surprising that the nation continues to invest substantial amounts in its weather forecast capabilities, including the satellites that are used to gather the necessary observations. However, cutting-edge scientific expertise and computing power are required to support technological advances, and the necessary resources are dispersed across several federal agencies. The Joint Center for Satellite Data Assimilation plays a key role in bringing together expertise from NASA, NOAA, and the Department of Defense to achieve the common goals of transitioning satellite data and research in satellite data assimilation into operational use.

The Joint Center is not just about weather and weather prediction. Many of the same data and many of the same methods that have proven to be successful for weather forecasting are now being used for a wide range of other environmental applications, such as air quality and aerosol forecasting, ocean data assimilation, and climate analysis and prediction. As the nation is preparing to take the next steps in space-based observing capabilities with the launch of the NPOESS and GOES-R programs, as well as new NASA research missions, the Joint Center is ready to help ensure that the return on the investment is maximized in terms of improved environmental analysis and prediction capabilities.

Lars Peter Riishojgaard
Director, Joint Center for Satellite Data Assimilation

Vision

An interagency partnership working to become a world leader in applying satellite data and research to operational goals in environmental analysis and prediction

Mission

To accelerate and improve the quantitative use of research and operational satellite data in weather, ocean, climate, and other environmental analysis and prediction systems

1 Background

The Joint Center for Satellite Data Assimilation (JCSDA) has been established to improve and accelerate the use of research and operational satellite data in numerical weather, ocean, and climate analysis and prediction. The formation of the center was motivated by a number of factors:

- The United States and its international partners are developing and launching new sensors and satellite systems based on the expectation that these sensors and systems will help dramatically increase the range and quality of environmental predictions. However, it is not enough to merely deploy and operate these new systems. A commensurate research and development effort must be put in place in order to ensure optimal use of the new data.
- Currently, satellite data comprise 99 percent of all observations received by operational weather and climate prediction centers. However, many types of observations are not yet fully utilized due to inadequate and underfunded scientific development.
- A substantial amount of human, financial, and computational resources is available in the United States to address these two issues. However, the resources are dispersed across several different federal agencies. A cohesive and coordinated national effort is required to accelerate scientific progress for both current and future satellite observations. Common goals, metrics, and algorithms will help accelerate and improve the use of satellite data among the major operational and research centers for weather and climate prediction.

The JCSDA provides a focal point for the development of common software and infrastructure for the partner agencies: the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the Department of the Navy, and the Department of the Air Force. The partnership allows these agencies to fully prepare for the upcoming flood of data from the advanced satellite instruments to be launched during the next five to ten years; such a partnership enables them to better achieve their mission goals. JCSDA research and development directly supports the NOAA and Department of Defense (DoD) operational environmental prediction responsibilities at home and abroad and supports NASA in its quest to improve our understanding the Earth's climate and in transferring its research to operational weather and climate forecasting.

2 JCSDA Partners and Structure

2.1 Partners

The key to the JCSDA's success is the partnership that combines resources and scientific talent of NASA, NOAA, and DoD to solve problems of mutual interest.

- NASA performs research and development to understand and protect our planet. NASA's Earth science program improves weather, climate, and environmental forecast duration and reliability through new space-based observations, assimilation, and modeling.
- NOAA's mission is to understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our nation's economic, social, and environmental needs.
- The U.S. Air Force and Navy partners develop and apply environmental science and technology to operational environmental prediction systems in order to support their missions and those of the other branches of the armed forces.

The primary groups and laboratories representing the agencies in the JCSDA are indicated in Figure 1.

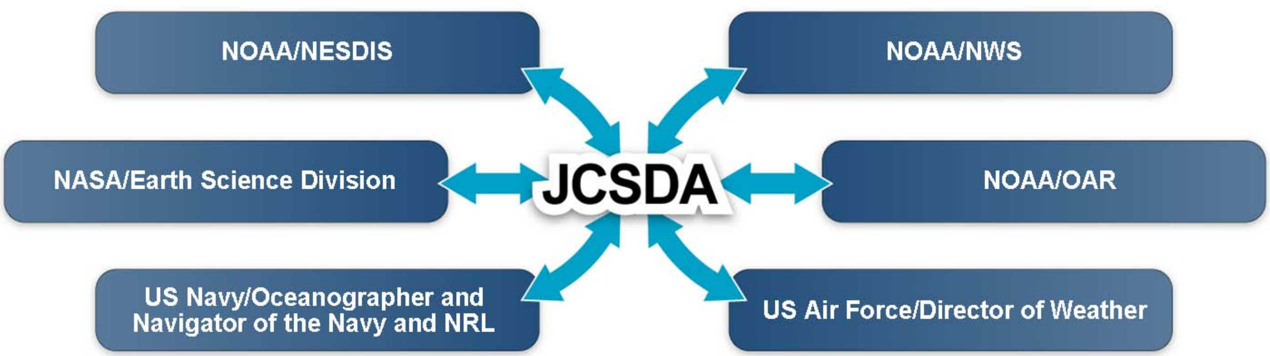


Figure 1. JCSDA Partner Organizations

2.2 Management Structure

The JCSDA is a distributed center—the majority of the work performed is distributed geographically and organizationally among NASA, NOAA, and DoD components with a small centrally located administrative staff.

The JCSDA consists of a Management Oversight Board (MOB), an Executive Team comprised of the Director, Executive Deputy Director, Agency Deputy Directors, and Chief Administrative Officer, and research scientists and support personnel.

The responsibilities of the MOB—which has representatives from NASA, NOAA, the Navy, and the Air Force—include reporting on an annual basis to their respective Agencies' executives concerning the operation of the JCSDA, providing recommendations on the budget and priorities related to the observing systems planned for use in the operational systems, and facilitating and sustaining cooperation among the sponsoring organizations/institutions.

In addition, the JCSDA is assisted by two advisory bodies: an Advisory Panel and a Science Steering Committee (SSC). The Advisory Panel provides high-level strategic guidance to the MOB on all activities of the JCSDA via recommendations from the individual Panel members. The SSC reviews the JCSDA scientific priorities and research and development program annually, with each member providing his/her recommendations to the JCSDA Director.

Figure 2. JCSDA Organizational Chart

3 Goals and Priority Activities

Short-term goals and priorities put in place by the JCSDA in order to address the lack of competitive forecast skill of current operational US systems are described in Section 3.1.
In order to accomplish its mission and make progress toward realizing its vision, the Joint Center has identified a number of science priority areas that are outlined in Sections 3.2 through 3.8. While these areas are very important, the short-term goals and priorities described in Section 3.1 take precedence.

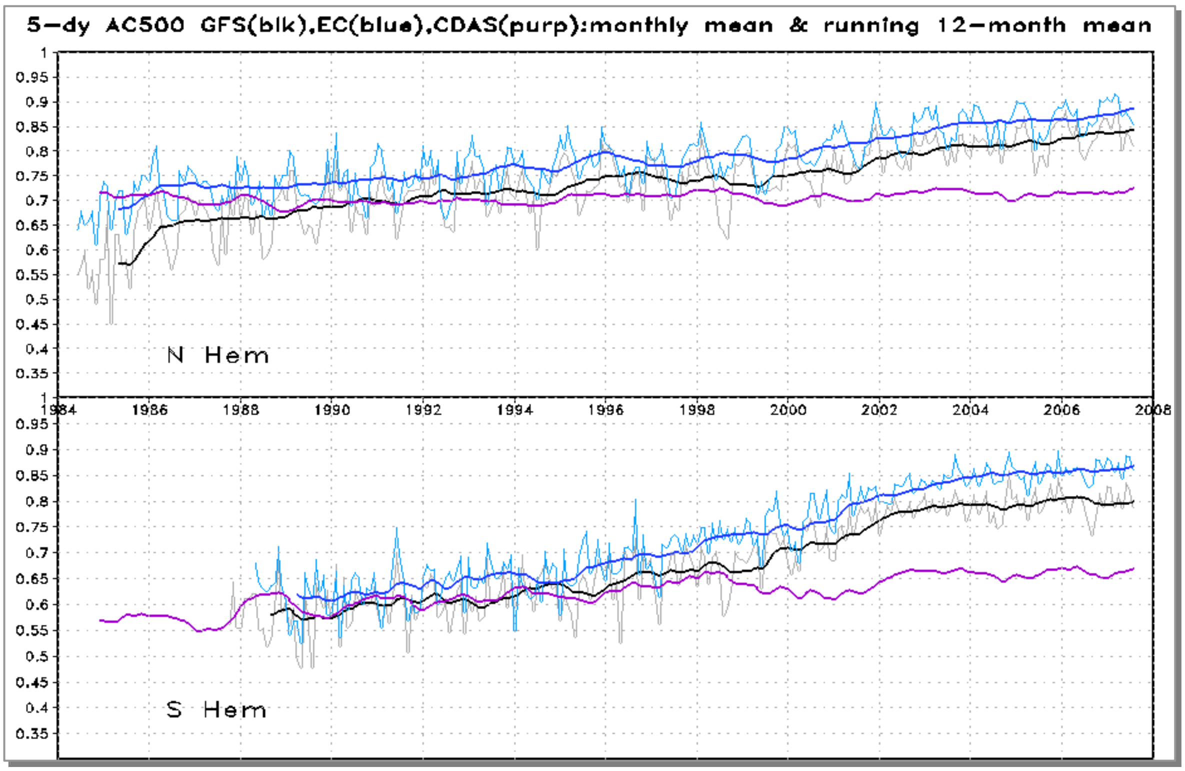


Figure 3. Day-5 forecast skill since 1984 (see text).

3.1 Short-term Goal and High-Priority Activities

As discussed earlier in the document (see "Message from the JCSDA Director," p. iii), the overall economic stakes in NWP are substantial. In other words, improved forecasting skill has a direct positive impact on the national economy.

Figure 3. shows the evolution over the last 20+ years of a key measure of skill at Day 5 for three different assimilation systems (additional plots illustrating the temporal evolution of skill are included in Appendix B). The black curve shows one of the JCSDA systems (the NCEP/EMC Global Forecast System), the blue curve shows ECMWF, and the purple curve shows skill from a reanalysis experiment using a frozen version of the EMC system over the entire period. The main message conveyed in this chart is that the forecast skill of the operational systems run in the United States is lagging significantly behind that of our international competitors. In the Southern Hemisphere, the gap appears to have widened since 2002. The most likely explanation

for this is better use of the space-based observations by our competitors, since Southern Hemisphere forecast skill is almost entirely attributable to the use of satellite data.

Both the vision and mission of the Joint Center are stated in broad terms and apply to modeling and data assimilation applications for the Earth system as a whole. However, in view of the limited resources currently available to the Joint Center and the particular challenges facing the nation in terms of maintaining competitive skill, the MOB and Executive Team have agreed that the Joint Center adopt as its *over-arching short-term goal*:

> **[C]ontribut[ing] to making the forecast skill of the operational NWP systems of the JCSDA partners internationally competitive by assimilating the largest possible number of satellite observations in the most effective way.**

The four most important activities to be undertaken by the Joint Center in support of this goal are described below in no particular order

Data Denial/Observing System Experiments (OSEs)

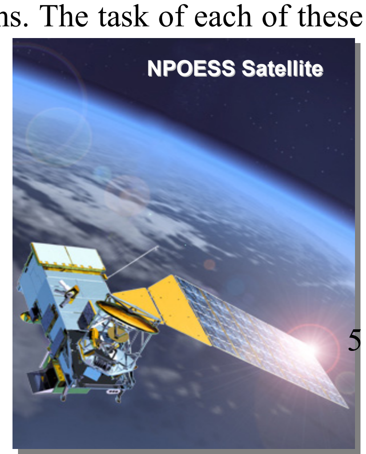
For each major system change and each major change to the Global Observing System, a comprehensive suite of data denial experiments for all major component of the observing system should be carried out. This is an effective way to monitor forecast impact sensor by sensor, to track consistency in data utilization and impact across the partners, and to track how well we are doing compared to other centers worldwide. Where applicable, this effort should be supplemented with adjoint sensitivity studies that will allow for more detailed analysis of such things as regional characteristics of impact and channel-by-channel differences of a particular sensor.

Community Radiative Transfer Model

Radiative transfer simulation is a critical piece of modern satellite data assimilation, and the Community Radiative Transfer Model (CRTM) is arguably the most important jointly developed and operated JCSDA system component. Enhancing the capabilities of the CRTM in terms of the use of current satellite sensors and preparing the model for future instruments are key priority areas for the Joint Center. Therefore, availability of a computationally efficient state-of-the-art radiative transfer model like the CRTM will continue to be a key component to the JCSDA's success.

Monitoring and Improvement of Satellite Data Utilization

It is important to realize that the task of maximizing the impact of a given data type does not stop when a new data type becomes operational for the first time. Success in NWP requires continuous monitoring and tuning of the assimilation of each individual data source. The Joint Center will form focus groups consisting of staff provided across the partners for each major satellite data type: infrared sounders, microwave sounders, surface winds, feature-tracking winds, microwave imagers, GPS radio occultation, and active systems. The task of each of these groups will be to continuously tune and improve the error covariance modeling, data selection, quality control and bias correction for their particular data type in order to maximize its impact. Even though the Joint Center partners all operate their own data assimilation systems, many satellite-related tasks are common to all of them. In order to maximize the sharing of information and



thereby help the partners make sensible decisions concerning the use of satellite data, the Joint Center will maintain a central repository of information about data utilization from the various sensors within each of the partners, including calibration issues, bias correction, data screening (including regional blacklisting), thinning and/or averaging.

Acceleration of New Sensor Implementation

One of the reasons for the relatively poor skill of U.S. NWP systems is the delay in operational implementation of new satellite data. Issues related to data flow, data formatting, CRTM performance, and error covariance modeling must be resolved and assimilation efforts must be resourced well in advance of the launch of upcoming sensors. The Joint Center has been quite successful in working with the parent agencies concerning the preparation for data from platforms either wholly or partly owned by the United States (e.g., NPP/NPOESS, GOES-R, DMSP F-16/17, Aqua, Aura, and COSMIC). The picture is less clear when it comes to data from foreign sources. Recent high-impact data from the European IASI and ASCAT sensors are not yet assimilated operationally by any organization in the United States, largely due to lack of funding for the necessary pre-implementation work. JCSDA will make it a priority to pursue funding for the necessary research and development to assimilate all relevant satellite observations irrespective of national origin.

Based on the current plans of space agencies inside and outside of the United States, the initial planning period (2010 to 2012) will include the deployment of a large number of new satellites and sensors. Appendix A shows a current list of upcoming launches of relevance for the Joint Center and its partners, including information about major applications targeted by each individual platform or sensors.

A key goal for the JCSDA is to reduce the total time it takes after the launch of a new sensor or data type to test, implement, and transition the assimilation methodology to the operational users. Historically, this process has taken anywhere from two to seven years. Shorter implementation and transition times will allow the new instruments to come on-line earlier, which will extend the useful life of each new instrument and accelerate forecast improvement capabilities.

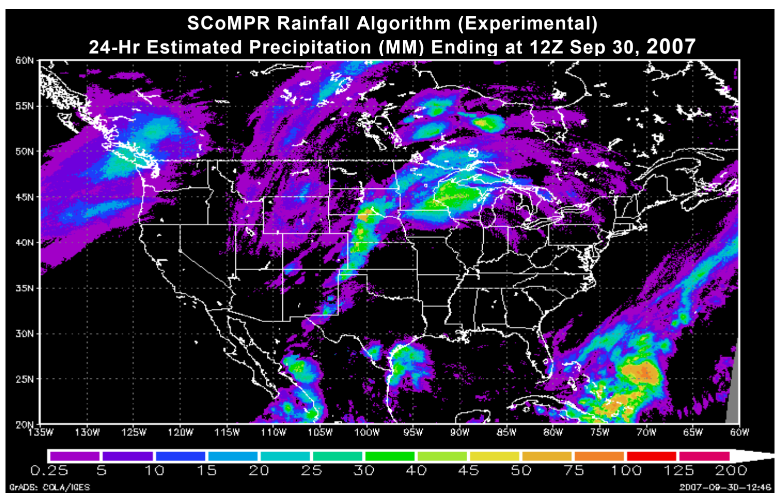
One of the initial goals for the planning period is to have all Meteorological Operational Satellite (MetOp) data fully utilized in NWP models during Calendar Year 2008. The Center plans to start impact tests for observations from the Atmospheric Dynamic Mission (ADM)/Aeolus and National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) as soon as the instruments are considered to be stable. An additional goal for both ADM/Aeolus and NPP is to have the transition to operations completed within one year after the launch of their respective satellites.

In addition to the four areas listed above, a cross-cutting theme will be the study of sporadically appearing anomalously low forecast skill (“drop-outs”). Typically, one or two forecasts from the NCEP global forecast system exhibit a dramatic loss of skill each month in both the Northern and Southern Hemispheres. Similar behavior has been noted in the Navy FNMOC global forecast system. This precipitous loss of forecast skill can account for a significant portion of the difference between the skill of the NCEP and Navy systems on one side and the ECMWF global forecast system on the other. In addition, addressing the underlying causes for these low-skill forecasts would also likely benefit the day-to-day skill as well. Scientist from several JCSDA partners are collaborating on identifying the causes of the adverse model behavior, which include possible quality control and bias correction deficiencies for some satellite data sets.

3.2 Radiative Transfer Modeling

Satellite remote sensing is based on the ability to infer physical properties of an object of interest—such as the atmosphere and the surface of the earth—from measurements of emitted or reflected electromagnetic radiation. Data assimilation can be based on either of the following two fundamentally different possible approaches to the problem of extracting the physical information from the radiance observations:

- **Assimilation of geophysical retrievals, in which the radiance measurements are converted into virtual observations of model variables, such as temperature and humidity**—These measurements are used to correct the model forecast of these same variables by the data assimilation algorithms.
- **Radiance assimilation, in which the conversion is carried out inside the analysis algorithm**—The model forecast is converted into simulated radiance observations, and the correction takes place in the space of the simulated observations.



Most current state-of-the-art data assimilation systems are based on the second approach, and the resulting impact of satellite soundings—especially in the microwave part of the spectrum—have been remarkable. Prior to 1998, satellite soundings were considered of marginal importance to Numerical Weather Prediction (NWP) skill at most centers. At the most recent World Meteorological Organization (WMO)-sponsored workshop on the Impact of the Global Observing System in Alpbach 2004, almost all major global centers cited satellite radiances as the single most important data type for NWP.

Irrespective of the particular approach taken, availability of a computationally efficient state-of-the-art radiative transfer model is one of the keys to success in satellite data assimilation. Current radiative transfer models are quite accurate at calculating radiances for clear atmospheric conditions. Radiances affected by clouds, by precipitation, or by the emissivity or reflectivity of the surface of the earth are much more difficult to model, and these radiances are currently assimilated only to a very limited extent. In some parts of the electromagnetic spectrum, this means that data over 95 percent or more of the horizontal locations are being discarded due to inadequate simulation capabilities. The physics of cloud and rain formation are non-linear and difficult to simulate with the systems currently used in data assimilation. Errors in observations and model predictions of clouds and precipitation are difficult to characterize. Large biases exist between cloud variables included in models and cloud variables observed by satellites.

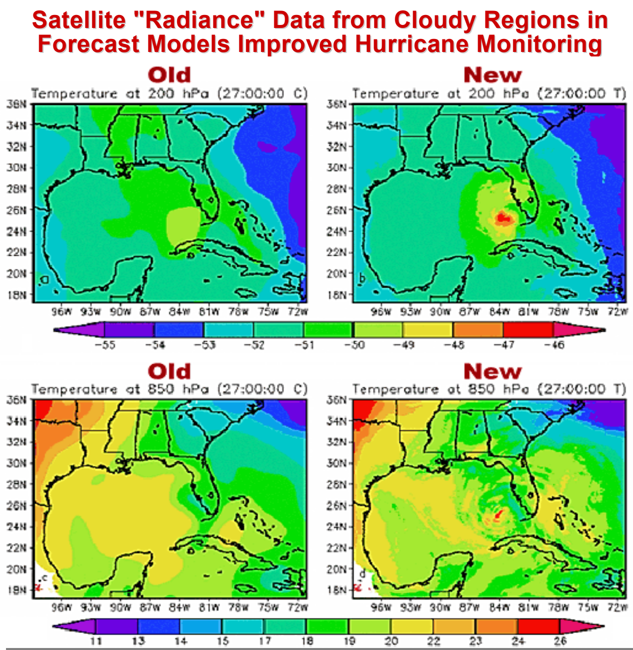
The JCSDA is a recognized world leader in the development of the radiative transfer models needed to assimilate satellite observations of the Earth in environmental analysis and prediction models and plans to consolidate and expand its efforts in this area.

3.3 Preparation for New Sensors

The United States and its international partners continue to develop and improve the satellite component of the Global Observing System. One of the main drivers of this development is the economic interest in having access to improved environmental analysis and prediction products. It is important to realize that in parallel to the investment in the spaceflight and ground system hardware, a substantial investment is needed in research and development in order to reap the full potential benefit of the observations that these new systems will provide.

Therefore, a major activity of the JCSDA is the development of the methodologies and associated software tools for assimilating the data from the next generation of advanced satellite instruments. These instruments will be flying on NOAA, NASA, and DoD satellites, as well as the satellites flown by international partners, e.g., in the context of the Global Earth Observing System of Systems (GEOSS). The large number of advanced meteorological sensors—including hyperspectral sounders, Global Positioning System (GPS) Radio Occultation, and active instruments, such as radars and lidars—will provide environmental data at spatial, temporal, and spectral resolutions never before achieved. In some cases, such as the European Space Agency's Atmospheric Dynamics Mission, they will provide measurements for which little or no prior data assimilation experience exists. The data volumes for some of the new systems will exceed those of today's systems by orders of magnitude. New instruments are also anticipated for the ocean and the land surface – wide swath altimetry, surface salinity, SAR-based observations of ice properties, internal waves, and spectral surface gravity waves, and active and passive measurements of soil moisture. Assimilating the information from these new sensors poses significant scientific, computational, and logistical challenges, but the potential benefits to environmental modeling are substantial.

3.4 Precipitation and Clouds



Precipitation and clouds are of particular interest to organizations developing and running data assimilation and forecast systems because accurate forecasts of the occurrence of these phenomena are high on the wish list of a wide range of end users and because precipitation and clouds pose real challenges for all links in the data assimilation chain.

From a data assimilation perspective, there are two aspects to this challenge:

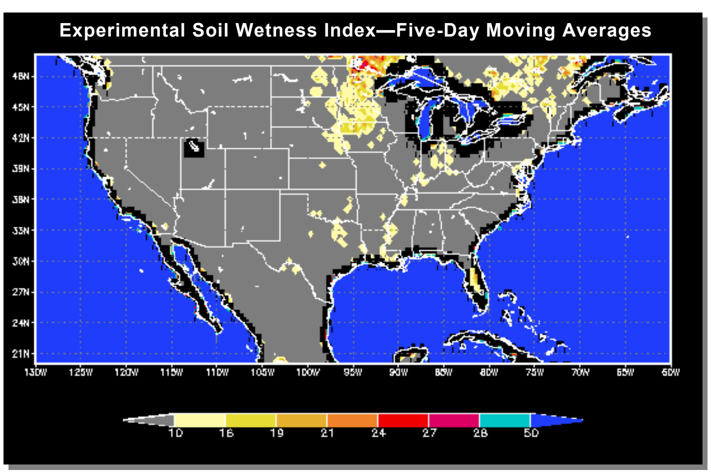
The notion of data assimilation in general is predicated on the assumption that we are able to predict the variables that are observed to a reasonable degree of accuracy. For the dry atmospheric variables (surface pressure, wind and temperature), this is a very good assumption. For observations relating to the hydrological cycle, this is not true to nearly the same degree, which put us at a relative disadvantage where assimilation of cloud observations is concerned: If the observed temperature in a given model grid cell is colder than what is predicted by the model, it is conceptually straightforward to correct this. But since the model may not always "know" exactly why a given grid cell is clear or cloudy, information about the observed cloudiness in that grid cell can easily be misinterpreted.

The other and related challenge is that clouds either directly or indirectly affect almost all satellite measurements. In some cases, such as for feature tracking winds and for active lidar measurements, clouds play a part in producing the signal. In others, such as for infrared sounding, clouds contribute to the measurement noise, or contaminate or preclude retrievals such as for SST and sea-ice concentration. An accurate description of the cloud field and of the radiative transfer involving the clouds is therefore crucial to making use of satellite data.

The stakes in simulating and assimilating cloud-affected observations are raised even further by the empirical fact that the so-called sensitive regions—those regions where numerical forecasts tend to be most influenced by initial condition error—often coincide with the presence of clouds. It is precisely these regions where much of the satellite data currently cannot be used, either because the infra-red (IR) sounders and IR and visible (VIS) imagers cannot penetrate the clouds or because the models do not capture the cloud field well enough for us to correctly interpret the cloud-affected observations.

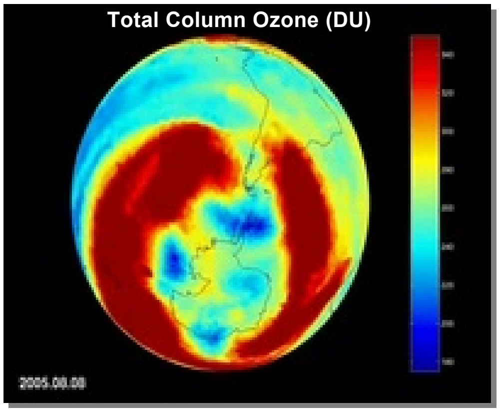
3.5 Land Data Assimilation

The land interacts with the atmosphere through exchanges of heat, moisture, radiation, and momentum. Modeling these processes is an important component of any atmospheric or climate prediction system. By observing reflected or emitted radiation at wavelengths for which the atmosphere is transparent, such as window channels, satellite instruments can see the surface. The magnitude and spectral distribution of the observed radiances provide information on vegetation conditions, surface temperature, snow cover, and radiative properties.



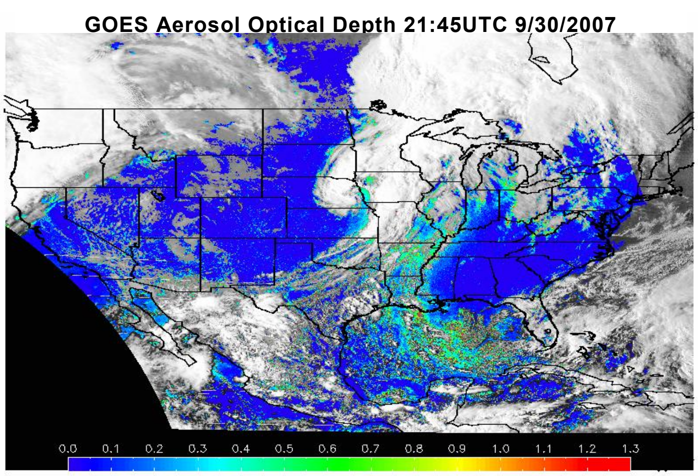
In contrast to the atmosphere, land data assimilation systems currently ingest retrieval products rather than radiances. A major obstacle to the variational assimilation of observed radiances—or the land surface products derived from them—is the lack of forward and adjoint models to relate the satellite observations to the variables of the land surface model. Direct assimilation of radiances is hampered by unknown surface reflectivity and emissivity dependencies. However, progress has been made to assimilate satellite retrievals of soil moisture, snow cover, surface temperature and water storage changes into land surface models using techniques such as the Ensemble Kalman Filter. One of the thrusts of the JCSDA is to bring these capabilities into the initialization of weather forecasts. The JCSDA partners have also used satellite data to improve the land surface characterization (e.g., vegetation types) for its land surface models.

3.6 Atmospheric Chemistry and Aerosols



Atmospheric chemistry and transport models are increasingly important components of environmental monitoring and forecasting systems. Air quality and aerosol data assimilation efforts are now being undertaken within the three parent agencies of the Joint Center, albeit for slightly different reasons. Atmospheric chemistry, the carbon cycle, and the link between atmospheric aerosol and the climate system are issues that are central to NASA's mission to improve our understanding of the Earth system and our own interaction with it. NOAA has a congressional mandate to provide operational air quality forecast products to its users. The primary interests of DoD in this area are associated with the impact of secondary atmospheric variables—such as visibility—on a range of military activities. While the requirements may differ somewhat from one agency to another, many of the fundamental scientific problems and algorithms are common, as are many of the datasets ingested in the various assimilation systems.

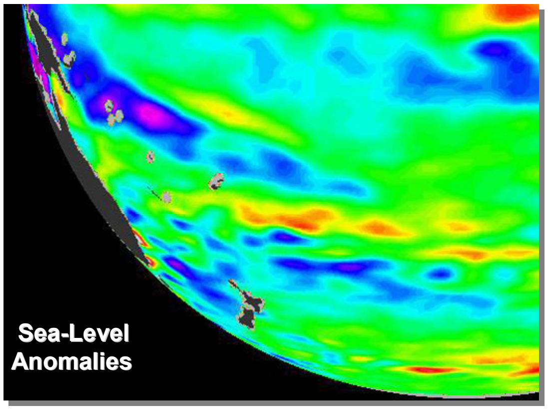
NASA, NOAA, and DoD all have interests in stratospheric chemistry modeling—in particular, ozone photochemistry and dynamics. Satellite data provide information about aerosol loading and about a number of atmospheric constituents, such as ozone, sulfur dioxide, carbon dioxide, carbon monoxide, and methane. Atmospheric chemistry models, when integrated with weather prediction and climate models, provide powerful tools for analyzing and predicting the evolution and distribution of greenhouse gases, quantifying the Earth's carbon cycle, and forecasting air quality, visibility, and UV exposure indices. Through modern multivariate data assimilation schemes, these activities also have a potential to improve weather forecasts in general.



Initially, efforts in pollution and visibility forecasting focused on simulating the passive transport of aerosols and gaseous pollutants with the wind fields predicted by the NWP models. However, the current strategy is to embed the chemistry within the NWP model, thereby allowing for two-way interaction between the minor constituents and the core model variables in terms of radiative transfer, transport, and cloud/aerosol microphysics.

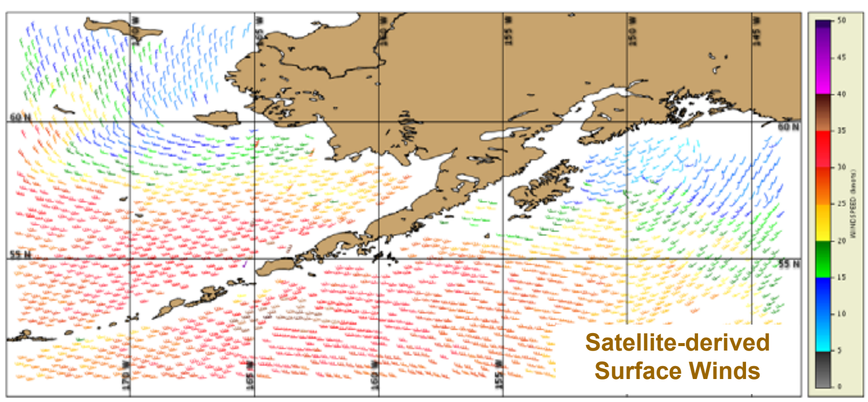
Major uncertainties remain in our knowledge of source terms (location, strength, temporal variability) for smoke, dust, and trace gases. These terms are difficult to estimate directly based on observations obtained from a network that is highly heterogeneous both temporally and spatially and in terms of capabilities. Data assimilation has the intrinsic capability of ingesting all of this information into one coherent framework and thereby contributing to a significantly reduction in these uncertainties.

3.7 Assimilating Ocean Observations from Space



Ocean data assimilation is now a well-developed technology with applications that span timescales from synoptic scale (marine safety, submarine operations, hurricane forecasting) to climate monitoring and prediction. Satellite observations provide data for ocean surface temperature, sea-ice concentration, surface height, significant wave height, wave spectra, and ocean surface color. Remotely-sensed surface salinity is on the horizon.

Satellite-derived marine surface winds incorporated into NWP models provide a critical upper boundary condition for ocean models used in data assimilation systems. The sea-surface temperature, wind wave height, and sea-ice concentration observations are critical not just to ocean predictions but also as lower boundary conditions for NWP and aerosol models. Hence, increasingly, the requirements and developments for atmospheric data assimilation and ocean data assimilation are becoming coupled. This is true whether the application is the initialization of coupled climate forecasts or of marine weather forecasts.



The current scope of ocean data assimilation activities within the JCSDA encompasses physical state estimates of the ocean in both the open ocean and coastal margins, as well as estimates of sea-ice concentration and ocean surface waves. The longer-term goal is to incorporate ocean (and coastal) ecosystem modeling to achieve the JCSDA's ultimate goal of contributing to a comprehensive environmental monitoring and prediction system.

The JCSDA partners have operational systems that assimilate existing remotely-sensed ocean observations. However the use of these satellite data—especially that from surface altimetry—needs further development to make better use of their information content. The problem is slightly different from that for the atmosphere since the ocean is for the most part opaque to electromagnetic radiation. The challenge, then, is to use the satellite observations at the sea surface to infer the ocean state at and below the surface. As with atmospheric assimilation, attention to covariance estimates and quality control issues are at the heart of effective use of the data.

The overarching priority for the ocean activities in the JCSDA is to address issues common to the different assimilation systems used by the JCSDA partners. These common issues are associated with the use of altimetry data and also spectral wave data. A short list of important goals includes: (1) advance the processing of altimeter data to improve the consistency between different data sources, and the estimates of tides, the geoid and mean ocean dynamic topography, (2) advance the use of altimetry in high resolution models both in the open ocean and in the coastal ocean, (3) develop common interfaces for data ingest, especially for new instruments such as Jason-3 and the Surface Water Ocean Topography (SWOT) mission, and (4) develop more sophisticated and physically-based assimilation methods for mean and spectral satellite observations of surface wind waves.

Another focus area that is shared between the ocean and atmospheric efforts concerns satellite observations of sea surface temperature which are now being included in atmospheric as well as ocean-only analyses. The issues include the effects of aerosols on infrared measurements, differentiating between analyses of skin vs. bulk SST, and the merger of observations from infra-red and microwave sensors with those from in situ measurements. Preparations for new instruments include attention to sea-surface salinity, an observation that will pose a challenge because of its high noise component.

3.8 Observing System Simulation Experiments

Over the next several years, the JCSDA parent agencies will need to make important decisions concerning future space-based observing systems. These decisions must be based on quantitative assessment studies wherever and whenever possible. High political, financial, technical, and scientific stakes in major observing system developments make it essential that these assessments be impartial and have community credibility.

Observing System Simulation Experiments (OSSEs) have become the de facto standard methodology for assessing the expected impact on forecast skill of proposed candidate observing systems for the atmosphere. Designing and executing credible and robust OSSEs is a major undertaking because it is necessary to simulate both nature and a set of reference observations paralleling what is obtained on a routine basis by the vast, complex, and highly heterogeneous Global Observing System. OSSEs for the oceans do not have a maturity level comparable to those for atmosphere, but are expected to become equally important in the coming decades.

It should be noted that OSSEs have an important role to play not only in the assessment of candidate future systems but also as a learning tool during the preparation for data from sensors already approved for funding and under development. In the OSSE context, important issues regarding the overall strategy and appropriate methodology for an instrument can be tested before it is even launched, thereby increasing the effective time period over which the end users can benefit from the investment in the new system.

JCSDA is uniquely positioned to coordinate a National OSSE effort that will benefit observing system developments within all three parent agencies. A state-of-the-art Nature Run, commissioned from the European Centre for Medium-Range Weather Forecasts (ECMWF), is currently being evaluated. Preparations for a comprehensive set of simulated observations are under way by three of the JCSDA partners.

The Joint Center plans to continue developing the OSSE capability into a national capability that can be used both to assess the impact of future systems and missions of all its parent agencies and to help prepare for assimilation of data from sensors to be launched in the near future.

4 Opportunities and Challenges

In its quest to help the partners meet their mission goals and satisfy the growing demands for reliable environmental prediction systems, the Joint Center will face a number of opportunities and challenges over the coming years.

4.1 Data Assimilation System Development

Satellite data are inherently asynoptic, and operational users require high-temporal-resolution data assimilation systems to use these data to their full potential. Experience in other major NWP centers worldwide has demonstrated the superior capabilities of next-generation assimilation methods—such as four-dimensional variational analysis (4D-VAR)—in terms of letting observational information pertaining to one particular model variable influence other variables, as well as creating more realistic analysis increments for individual observations. The requirements and developments for atmospheric data assimilation and those for the ocean, land and sea-ice data assimilation are becoming increasingly interrelated, hence we anticipate that the JCSDA partners will also be undertaking developments that consider more the coupling between components.

It is evident that the Joint Center needs next-generation data assimilation capabilities in order to accomplish its mission, but the JCSDA is not responsible for the data assimilation system development per se. Currently, the Center partners are developing multiple options for such systems. While it is expected that these new systems will provide a substantial boost to the overall capabilities of the Center, it will be a challenge to maintain the largest possible number of joint components in order for the partners to be able to share and transition their research as seamlessly as possible.

4.2 Computational Environment

Data assimilation is one of the most computationally challenging applications. At the present time, the JCSDA partners do not have a unified strategy to address this challenge, in part because the assimilation systems are different and in part because major computer procurements are being handled separately by the individual parent agencies. However, according to current plans, all JCSDA assimilation systems will be of significantly higher resolution than today's systems, and by the 2010 timeframe, they will employ more computationally intensive ensemble and/or 4D-VAR-type algorithms. This is a highly desirable development in terms of obtaining maximum impact from asynoptic satellite data, but the computer resources needed for this advanced technology exceed those of the current 3D-variational systems by a factor of 10 or more for a given spatial resolution.

5 Implementation

Implementation of the Joint Center mission consists of three major elements: internal (directed) research, external research grants, and training. The Directed Research Program is aimed at near-term efforts to bring recent developments and new satellite data to the threshold of operational implementation. The External Research Program is designed to support longer-term research and development projects and to take advantage of the knowledge represented by the broader research community in areas where the Center has identified gaps in the expertise available among the JCSDA partners.

5.1 Directed Research

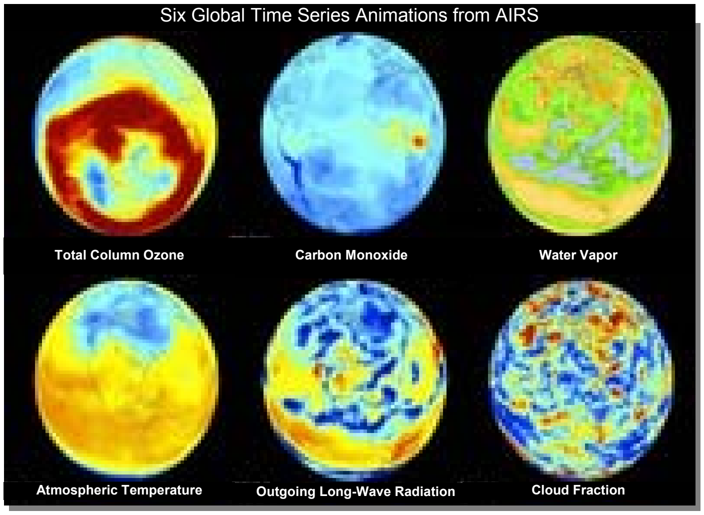
The Directed Research Program primarily supports development activities at the partner organizations. It takes advantage of the in-house expertise in satellite remote sensing, radiative transfer, data assimilation, and numerical modeling. Priorities for the program are assigned on a year-to-year basis, and projects focus on rapid research-to-operations transitions and on developing and exercising major JCSDA infrastructure. The funding for this element is a mix of dedicated funds made available for JCSDA purposes by the parent agencies and in-kind contribution from the JCSDA partners. The Joint Center Executive Team provides coordination, assisted by the Technical Liaisons.

5.2 External Research

The purpose of the JCSDA grants program is to partner with the external research community by funding longer-term projects within the six priority areas discussed in Chapter 3. The External Research Program is distinct from the Directed Research Program because it has a more far-reaching vision. Furthermore, since the recipients of the grants are mostly external to the Joint Center, the technological readiness levels of the efforts supported under this program are typically lower than for the Directed Research Program. However, projects under this program are encouraged to make use of JCSDA's shared infrastructure components—such as the CRTM and the Grid Statistical Interpolation (GSI)—to control cost, avoid redundancy, and facilitate the transition into operations of successful efforts. Successful efforts under the grants program are expected to lead to subsequent effort under the Directed Research Program and will ultimately lead to transfer into operational implementation.

The recipients of JCSDA funds under this program are selected via a competitive process based on proposals submitted in response to a Federal Funding Opportunity (FFO) Announcement. Funding for the FFO has been provided by all of the partner agencies, but for practical purposes, the Center decided to pool the funding from all sources and let one agency be responsible for administering the FFO on a rotating basis. For fiscal years 2003-2008, NESDIS/STAR has been administering the FFO on behalf of all the JCSDA partners.

5.3 Training, Education, and Outreach

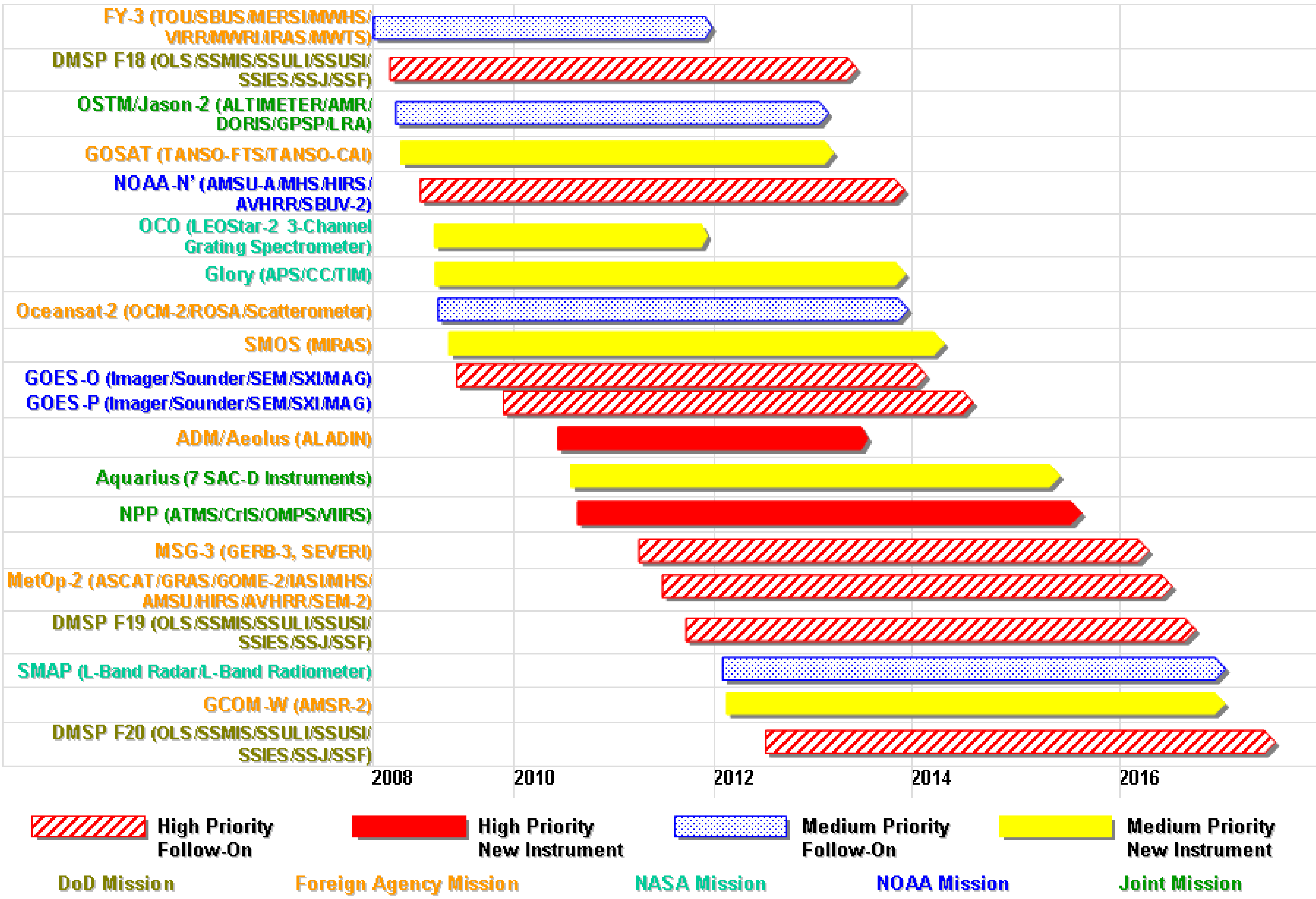


While the number of scientists working in satellite data assimilation and related activities is growing, there is no commensurate output of scientists with data assimilation background or training from universities. In fact, no major academic program exists today that specifically targets the needs of the community in terms of providing strategic research and a constant influx of new researchers with data assimilation expertise.

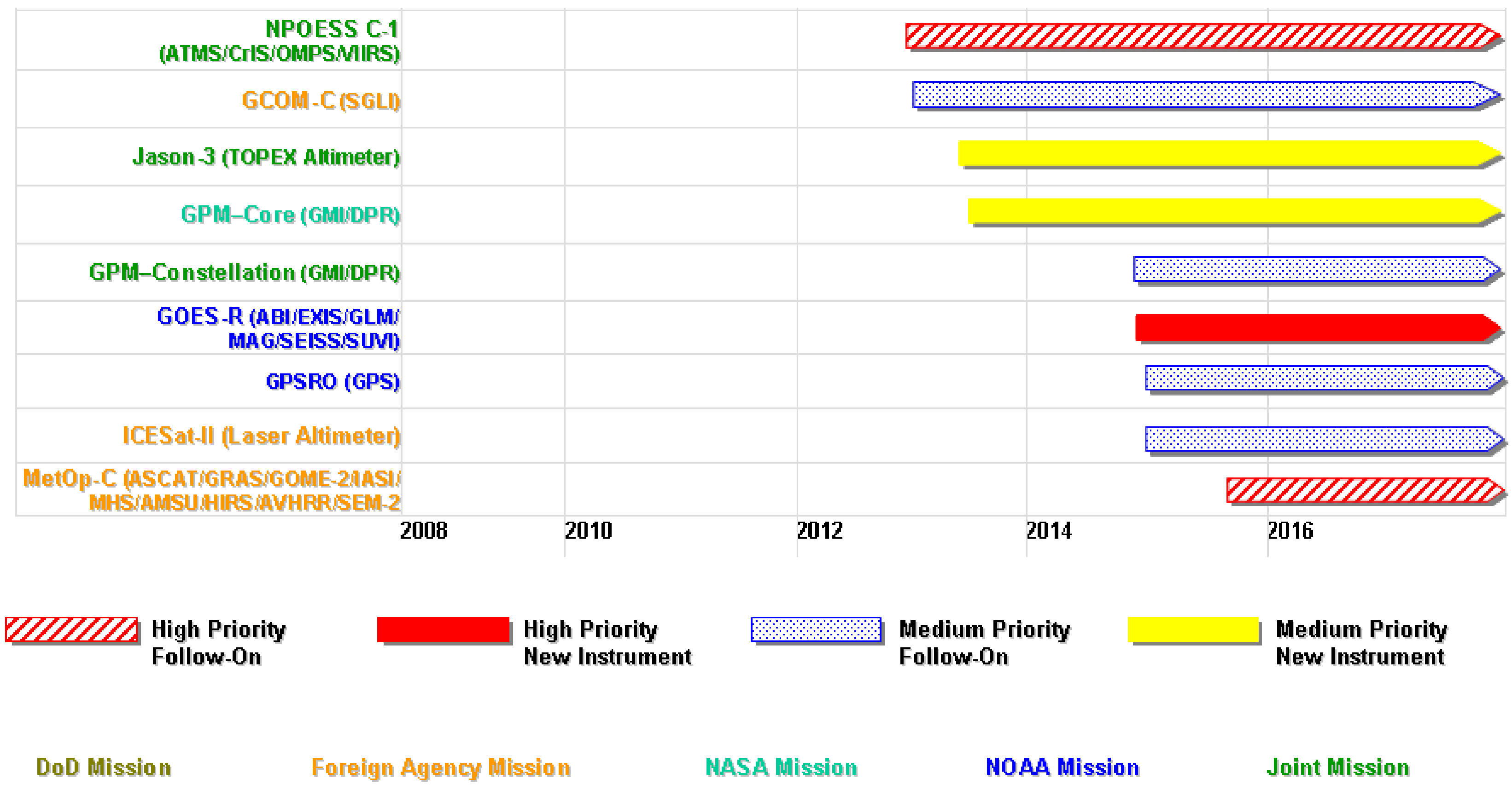
The Joint Center is not in a position to fill this void alone, but it maintains close links to the university community and will attempt to address the underlying issues in various ways. First, JCSDA has hosted and plans to continue hosting workshops both for research and for training purposes. Second, the JCSDA has plans to organize a two-week summer colloquium with internationally recognized lecturers in atmospheric, land, and ocean data assimilation. Third, the JCSDA intends to support, in concert with its partners, a vigorous and focused internship program that offers promising graduate students—M.S., Ph.D., and post-doctoral—hands-on opportunities to learn and contribute to ongoing and cutting-edge satellite data assimilation activities. The Joint Center is confident that these opportunities will have a significant, far-reaching, and positive impact on the community and will result in outstanding candidates to lead future data assimilation activities.

Appendix A: Upcoming satellite missions of relevance for the Joint Center for Satellite Data Assimilation

Upcoming Missions—FY10 through FY12



FY13 through FY15



Appendix B. Progression of forecast skill since 1996

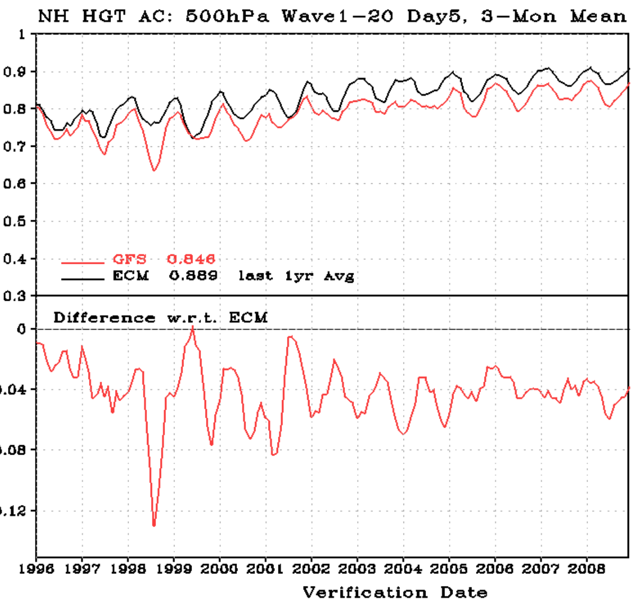


Figure B. 1 Northern Hemisphere 500 hPa anomaly correlation coefficients at day 5 for ECMWF (black), NCEP (red); lower panel shows difference.

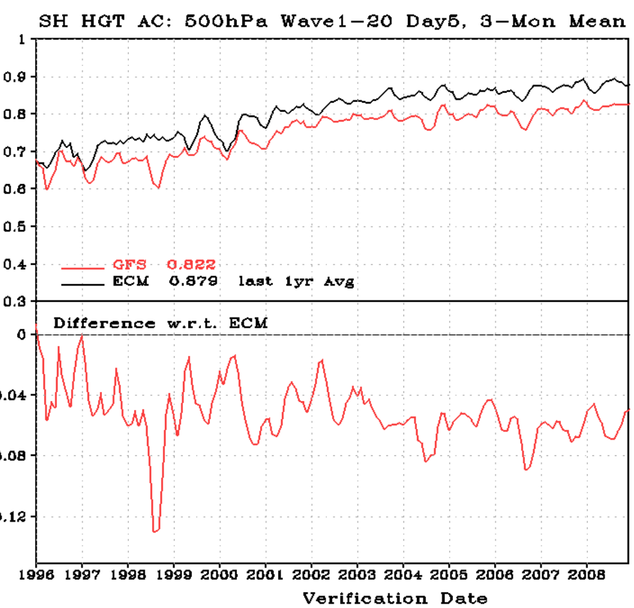


Figure B. 2 Southern Hemisphere 500 hPa anomaly correlation coefficients at day 5 for ECMWF (black), NCEP (red); lower panel shows difference.

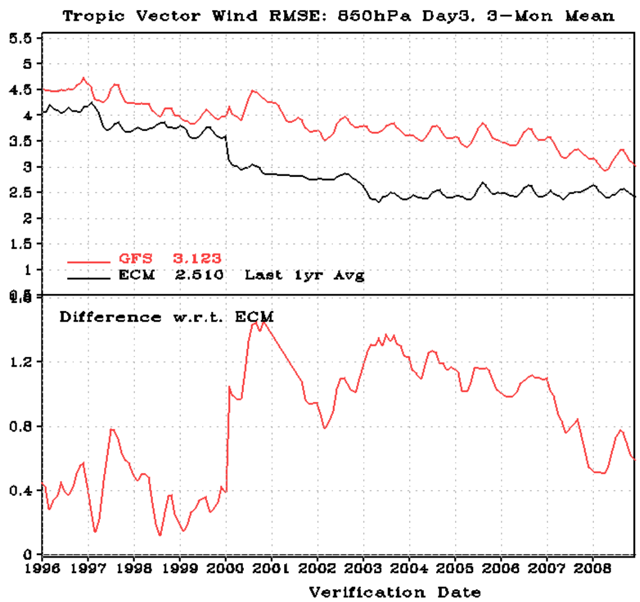


Figure B. 3 Tropical 850 hPa wind RMS error at day 5 for ECMWF (black) and NCEP (red); lower panel shows difference.

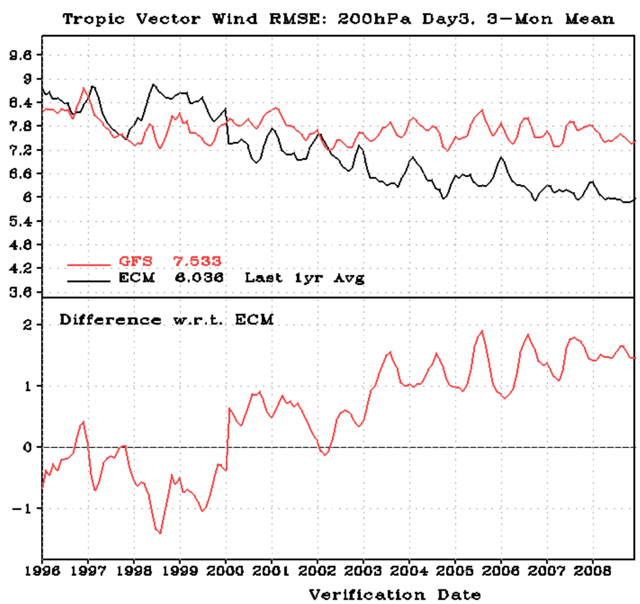


Figure B. 4 Tropical 200 hPa wind RMS error at day 5 for ECMWF (black) and NCEP (red); lower panel shows difference.